Simulating With Storms

RMA2 provides the capability to include storm fronts in your simulation. This is accomplished by generating spatial variations in wind speed and direction for each time step based upon a user specified set of criterion for the storm(s). These criteria include factors such as:

- storm path
- orientation of the storm along the path
- storm speed
- shape
- temporal growth and decay constant for wind

Note: Storm rotation is based on the Coriolis forces for the northern hemisphere.

To date, the two dimensional Mississippi River Gulf Outlet study is the only application at WES in which storms were used to provide the wind stress. Because of lack of experience in this area, this feature remains experimental.

Storms In A Simulation

Many open water systems are strongly influenced by meteorological forcings which can apply pressures at the water surface. These wind stresses can be from a variety of storm types. The wind effects can generally be classified either as steady in nature or associated with a dynamic event. The ability of RMA2 to adequately simulate a real-world event must be carefully evaluated for each of these classes.

The response of a water body to wind forcing will generally be three-dimensional. The surface wind stress will drive a surface current in the direction of the wind. The influence of that surface wind drift will then be dependent on the water depth and the local shoreline geometry. If the currents are directed to a shoreline, the movement of surface water will result in a pilling up of water on that shoreline. As the water level is raised on the shore, a hydrostatic pressure gradient is developed perpendicular to the shore, which will in turn drive a return flow away from the shore in the bottom portion of the water column. This vertical circulation pattern will moderate the increase in the water level at the shoreline. The strength of that return flow will be dependent on the water depth; generally stronger in shallower water.

The process is however a dynamic one. During the initial movement of water toward the shoreline, there is insignificant return flow at the bottom. Only after the water level is dramatically affected does the three-dimensional circulation develop. Wind events associated with stationary meteorological conditions may generate persistent unidirectional winds for prolonged periods of time, which may fully develop vertical circulation cells in the water column. However, there are a large number of wind events that are of a shorter duration and do not involve a fully developed vertical circulation response.

RMA2 Considerations

The three-dimensional nature of the circulation affects how appropriate the application of a depth-averaged model will be to the problem. It has been shown that for a steady-state type of wind forcing, RMA2 will overestimate the setup of the water levels at the shoreline. However, for dynamic events, the model will generally perform well for the initial movement of water. If the dynamics of the storm lead to a change in the wind stress such that a steady-state condition is never approached, then RMA2 will yield reasonable results.

If the shape of the shoreline is more complex, horizontal variations of the water surface may result in localized return flows that do not involve significant vertical circulation. Such circulation patterns are directly analogous to rip tides along a beach in response to the radiation stress of the waves.

The ability of RMA2 to properly simulate wind forcing hydrodynamic response is limited to cases where steady-state conditions are *not* approached. RMA2 will result in a raised water surface, or “setup”, at the shoreline, but because of the depth averaging, will have no return flow. Technically, RMA2 gives the appropriate “average velocity” for such conditions. However, if water quality or any dispersive processes are of interest, the results must be interpreted with care. In addition, the water surface setup will normally be overestimated.

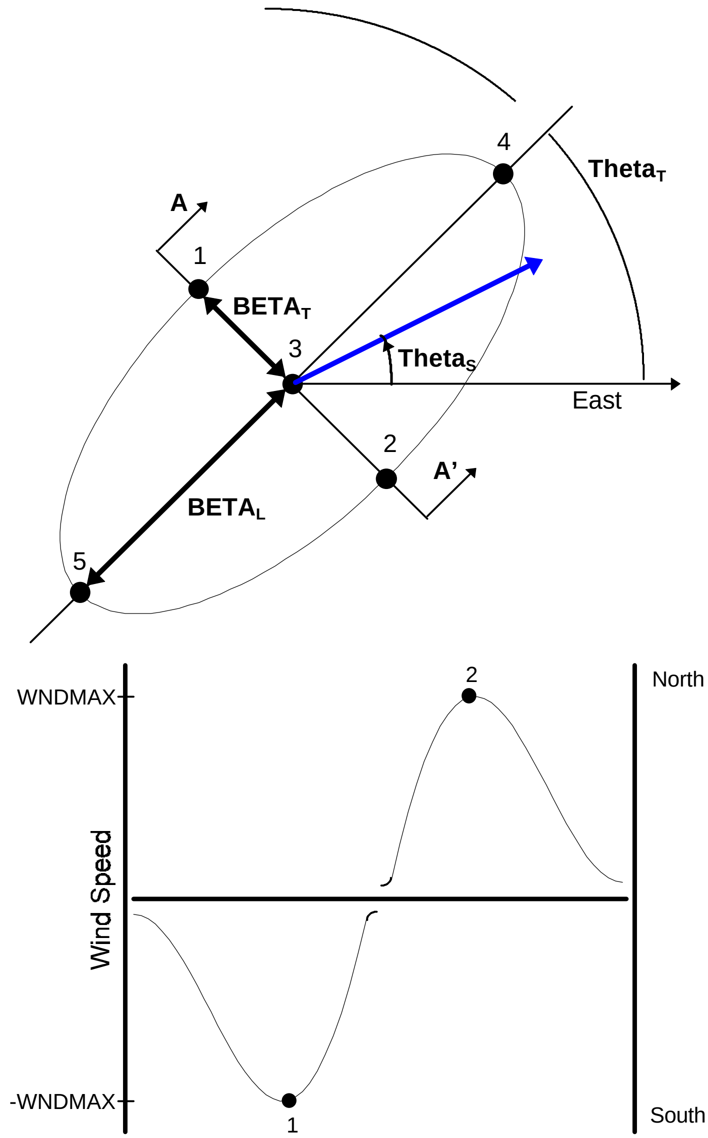
RMA2 can adequately handle certain types of dynamic events. The response of a system to a frontal passage or tropical storm can be evaluated with some confidence level by RMA2, provided the storm does not stall, which will lead to some steady-state issues.

Defining Storm Events

The representation of storms within RMA2 is provided as a means of easily developing relatively complex wind fields. A “storm” in RMA2 is defined as a specific tracking of the location of the storm center as a function of time, and the characteristics of that storm.

A storm is defined using the BWS card. Each BWS card creates a single storm. You may simulate multiple storms (presently dimensioned to two) to describe complex wind patterns by including additional BWS cards.

The storm characteristics are as described below. Refer to this illustration.



Storm Cross Section A to A’

The Storm Reference Point

There are several options regarding the placement of the storm reference point relative to the numerical mesh. Referring to the figure, the reference point, ISTYPE, can be defined as either:

1. The location of maximum winds along the positive minor axis
2. The location of maximum winds along the negative minor axis
3. The center of the storm
4. The location of maximum winds along the positive major axis
5. The location of maximum winds along the negative major axis

These options are designed for convenience in obtaining the desired wind direction at a particular place and time when used in conjunction with other variables.

Time And Place Of The Occurrence Of Maximum Winds

The initial position of the storm is back tracked based on the storm tracking speed and direction of storm movement. The RMA2 simulation time, TREF, in decimal hours, is when the storm will arrive at the designated reference node, NREF, where NREF defines the location of the storm reference point. This places the peak winds relative to a specified time of the model simulation.

The pairing of location and time, combined with the storm path direction are used to develop the full storm track during the simulation. Based on the reference storm location and time specified, RMA2 will perform all calculations to determine past and future storm movements.

Storm Tracking Speed

The speed, SSPD, in miles per hour (mph) of the storm across the study domain.

Storm Major Axis Dimension

The longitudinal distance, $BETA_L$ from the storm center to the point of maximum wind speed, in feet or meters depending upon the setting of the SI card. The major axis is generally defined as the long axis.

By defining the major spatial axis as *large* relative to the minor axis dimension, a cold front storm can be simulated. This will normally require the major axis to be *very* large relative to even the model mesh dimensions. A Hurricane type storm can be simulated by choosing both the major and minor axis as having the same value, creating a circular storm pattern.

Storm Minor Axis Dimension

The transverse distance, $BETA_T$ perpendicular to the major axis from the storm center to the point of maximum wind speed, in feet or meters depending upon the setting of the SI card.

Maximum Wind Speed

The maximum wind speed, WNDMAX, in miles per hour (mph) will define the maximum winds along the ellipse defined by the major and minor axes.

Minimum Wind Speed

The minimum wind speed, WNDMIN, in miles per hour (mph) will define the minimum winds within the storm.

Growth And Decay Constant Relative To Maximum Winds

The exponential temporal decay coefficient, DECAY (hr), is a Gaussian variance of wind speed relative to the time of maximum winds. This parameter facilitates the specification of daily wind patterns and tropical storm growth. This constant is normally derived from field data. A typical value for daily winds would be 6 hours.

Orientation Of The Major Axis Of The Storm

The direction $THETA_T$ of storm orientation in degrees counter-clockwise relative to the positive *x* axis. This is significant for frontal passages to get the spatial variation of winds properly prescribed over the model mesh.

Direction Of Storm Movement

The direction toward which the storm is moving, $THETA_S$, is the storm track in degrees counter-clockwise from the positive *x* axis.

Note: This direction does not have to match the orientation of major axis.